Proceedings of the Nature Reserves Survey Seminar.
Gardens' Bulletin Singapore ***49*** *(1997) 333–352.*

Odonata Biodiversity in the Nature Reserves of Singapore

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Abstract

An account is given of Odonata collected during the survey of the Nature Reserves. Most of the species described from Singapore material in A.R. Wallace's collection in 1856 still occur. A total of 79 species have been recorded within the Nature Reserves, including an endemic damselfly, *Drepanosticta quadrata*. Eight species are known only from Nee Soon Swamp Forest.

Introduction

The Odonata are a relatively well studied group whose aquatic larvae are carnivorous and thus not limited by distribution of specific plants, but which are known, at least in some cases, to be affected by the nutrient status and ambient properties of the water they live in.

The insect order Odonata (Plate 1) consisting of dragonflies and the smaller, more slender forms called damselflies, is represented in Southeast Asia by members of 14 families. Where known, all regional forms have aquatic larval stages so a biodiversity survey of the group must be related to the diversity of wetlands available in the area, even though many species range far from their breeding grounds as adults. However, there remain many species for which the larvae remain unknown and the existence of terrestrial larvae in other regions, such as in *Megalagrion oahuensis* in Hawaii (Williams, 1936), suggest some caution even in this assumption.

The Central Catchment Nature Reserve (CCNR) together with the adjacent Bukit Timah Nature Reserve lies near the centre of Singapore, remote from the coast so that essentially maritime species can be at most only casual visitors. The function of the area as a water catchment implies that polluted waters are essentially excluded, though in fact some institutional land, golf courses, parkland and a closely monitored zoological garden do fall within its drainage area.

The reserve area lies wholly within the central granitoid core of the island at the focus of the main headwaters of streams flowing north, south and east, now impounded to form four reservoirs supplying the potable

water grid of the city, and whose input is supplemented by water imported from Johore. The high ground is largely 'tree country' in the sense of Johnson (1967), though of very varied forest quality, mostly a mosaic of secondary vegetation with a few pockets retaining primary character.

The odonate fauna may be expected to reflect the extent to which the original forest stream, pool and swamp biota have survived the intense human exploitation over almost two centuries as described by Corlett (1992). It will also reflect the impact of large water bodies wholly foreign to the original hydrography of the island, the loss of major open streams to impoundment or canalisation, and, most recently, the conversion of a largely rural and agricultural terrain to one now wholly urban, industrial and recreational. This study of the CCNR can only address some of these aspects. An account of the odonate fauna of the island of Singapore as a whole is deferred to a later communication.

History

The first collection of Singapore dragonflies seemed to be that assembled by Alfred Russell Wallace during his six-month stay in 1854 prior to his travels through the Malay Archipelago. No list was ever published, but in a short paper entitled 'The entomology of Malacca', Wallace (1855) mentioned that in Malacca he '... nearly doubled my collection, which now amounts to 72 species of true dragonflies.' He must have taken over 36 species in Singapore but even so only 26 species have been accounted for in literature available to me. None of the Wallace material could be unequivocally assigned to the existing CCNR since his material was simply labelled 'Singapore'.

The next important contribution was by Laidlaw (1931) and this time, using material in the Raffles Museum, he gave actual location, date and collector, writing 'I have attempted to note all records for Singapore as it occurs to me that such records may be of particular interest in view of the many changes which have been in progress in the Island in the last hundred years or so.' Laidlaw himself seemed never to have collected in Singapore and the material came from collectors who were not specialists in Odonata capable of specific search. Most locations mentioned were not within the reserve.

The next important contribution was a comprehensive catalogue for the Malesian region (Lieftinck, 1954) in which Singapore island is frequently cited specifically but without internal locations. Although many interesting new records were made, it was striking that very few of the forest species found by Wallace had been recollected. Far from indicating their extinction

however, this appeared only to reflect limitations of the collecting habits of the workers concerned. After the Lieftinck catalogue, only a few small lists were on record that could be localised to the CCNR area (Paulson, undated; Iwasaki, 1981; Kiauta & Kiauta, 1982; Yokoi, 1996) besides occasional notes in special literature (e.g., Murphy, 1994).

Methods

During the formation of the collection on which this paper is based, an attempt was made to reach all known stream-lines in the reserve, many of which were remote from normal access (Figure 1). A policy of mapping all penetrations of the area was adopted and in fact the geographical survey became a significant component of the work in its own right. The problem of locating and recording individual collecting sites in such remote terrain presented some difficulty.

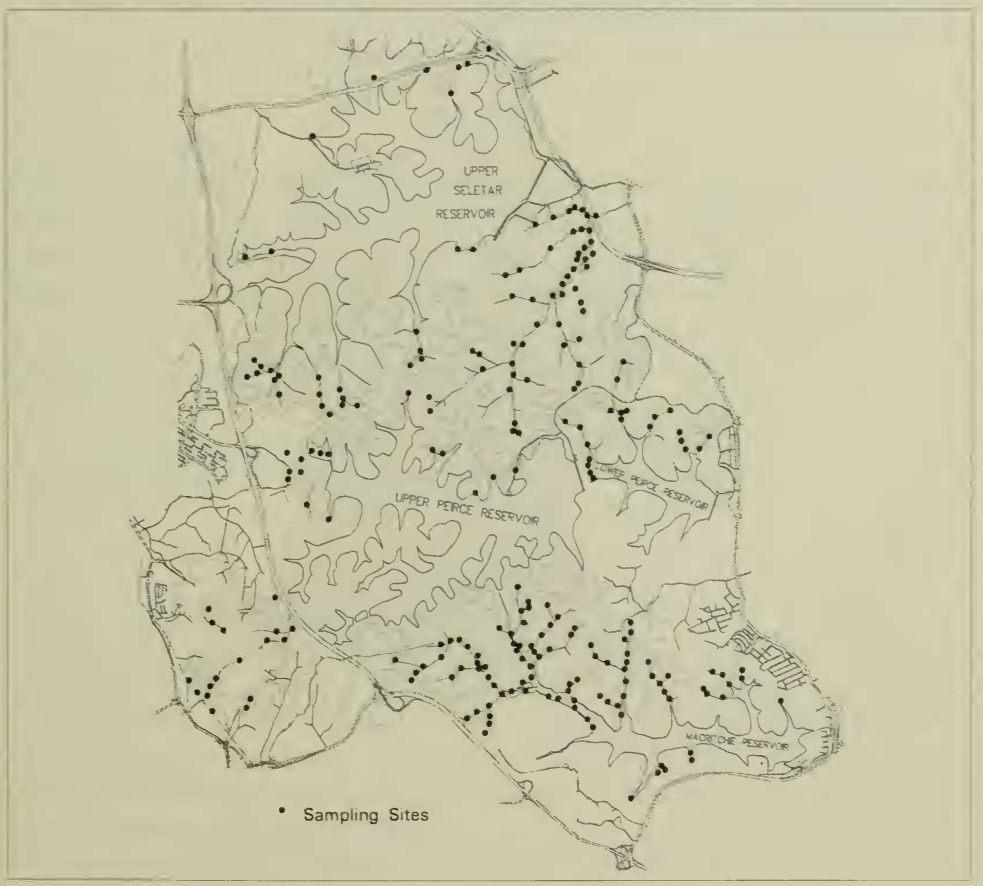

Figure 1. Locations of sampling sites.

Since the CCNR has most (three out of four) of its stream systems impounded to form reservoirs, this allowed us to code the sectors in the following manner. In each reservoir, the major inlets were lettered anticlockwise (A being the outlet) and streams entering each inlet received this code with appropriate subscripts to identify them and their various tributaries. A similar system was found workable in the unimpounded Nee Soon Swamp Forest.

Adult dragonflies were collected by hand-net at selected points during the mapping operation, wherever local conditions permitted. Because many forest streamlines were choked with hooked rattans or pandans, this was inefficient and some records by sighting alone had to be made. In genera with closely similar species (e.g., *Gynacantha* and *Vestalis*) only a generic name could be applied and in such cases had to be discounted in mapping distribution. A limited amount of larval collection and rearing was also undertaken. Identification relied on available regional literature and an unpublished generic key of my own, and all have been checked by M. Hämäläinen. Names conform to those in van Tol (1992).

Results

Table 1 lists the dragonfly and damselfly species collected from the reserve area during the survey period 1994 to 1998 and some previous confirmed records. A total of 79 Odonate species have been recorded from within reserve limits out of a total of more than 100 now known from the whole island. This total now excludes some species previously reported in error. The Singapore list now included 36 species not previously recorded from the State, most of these taken during the period of this survey although not all from within the reserve area. Some of these were common species, which were to be expected but some are rarities of some significance. For example, *Aethriamanta aethra* (Plate 2a) is the first record for Singapore and the Malay Peninsula and *Orthetrum luzonicum* is normally considered a montane species but found in Singapore.

Probably the commonest dragonfly in Singapore is *Neurothemis fluctuans* whose brown-winged males are seen everywhere around marshy spots, grassy pools and open stream sides. It penetrated the CCNR along road-sides and open tracks and can be common quite deep in open secondary forest. Yet, this species was never associated with true forest streams. Its very abundance might have contributed to our failure to record the related *Neurothemis disparilis*, reliably recorded from Singapore (Laidlaw, 1931), which perhaps could be mistaken for a teneral or female of *N. fluctuans*.

Table 1. Dragonflies and damselflies collected during the Nature Reserves survey. (1–New Record for Singapore, 2–Singapore is type locality)

Species	Status in Nature Reserves	Singapore general
Suborder **ZYGOPTERA** (Damselflies)		
Family **Amphipterygidae**		
Devadatta argyoides[2]	Local. Bukit Timah	-
Family **Calopterygidae**		
Vestalis amethystina	Frequent	-
Vestalis amoena	Local (Nee Soon)	-
Family **Chlorocyphidae**		
Libellago aurantiaca[2]	Local (Nee Soon system only)	-
Libellago hyalina[1]	Rare (Nee Soon only)	-
Libellago lineata	Rare	-
Family **Euphaeidae**		
Euphaea impar[1]	Local	-
Family **Lestidae**		
Lestes praemorsus[1]	Locally common (MacRitchie only)	-
Platylestes heterostylus	?Bukit Timah	-
Family **Megapodagrionidae**		
Podolestes orientalis[1]	Local	-
Family **Platycnemidae**		
Coeliccia albicauda[1]	Rare. 1 Seletar U	-
Coeliccia octogesima[2]	Locally common	-
Copera marginipes	Rare	Common. widespread
Family **Platystictidae**		
Drepanosticta quadrata[2]	Common	-
Family **Pseudagrionidae**		

Species	Status in Nature Reserves	Singapore general
Aciagrion hisopa	Occasional	Occasional
Agriocnemis femina	Local	Common, widespread
Agriocnemis nana	Local	-
Amphicnemis gracilis[1]	Swamp forest only	-
Archibasis melanocyana[1]	?Rare, reservoir	-
Archibasis viola[1]	Local	-
Argiocnemis rubescens	Local	-
Ceriagrion cerinorubellum	Local	Common, widespread
Ischnura senegalensis[?1]	Local	Common, widespread
Onychargia atrocyana[2]	Occasional	Old record (type)
Pericnemis stictica[1]	Frequent	? any bamboo area
Pseudagrion australasiae	Common, reservoirs	Occasional
Pseudagrion microcephalum	Common, open streams	Common
Pseudagrion pruinosum[1]	Rare	-
Pseudagrion rubriceps[1]	Rare	-
Teinobasis ruficollis[2]	Local U.Mac.conv.	-
Family **Protoneuridae**		
Prodasineura collaris	Local, widespread	-
Prodasineura interrupta[2]	Local, Nee Soon catchment	-
Prodasineura notostigma[2]	Local, widespread	-
Suborder **ANISOPTERA** (Dragonflies)		
Family **Aeschnidae**		
Anax guttatus	1 (mist net)	Common
Gynacantha spp.	Visual sightings	Occasional
Oligoaeschna amata	Rare	Old record
Tetracanthagyna plagiata	Rare, Nee Soon Swamp Forest	Old record
Family **Corduliidae**		
Epophthalmia vittigera	?Common (reservoirs)	Occasional
Family **Gomphidae**		
Burmagomphus divaricatus	Local, Nee Soon SF	-
Heliogomphus kelantanensis[1]	Local, Nee Soon SF	-

Species	**Status in Nature Reserves**	**Singapore general**
Ictinogomphus decoratus	Common, reservoirs	Common
Macrogomphus quadratus[1]	Local but widespread	-
Microgomphus chelifer[1]	Local (Nee Soon SF)	-
Paragomphus capricornis	Rare	-
Family **Libellulidae**		
Acisoma panorpoides	Local	Common, widespread
Aethriamanta aethra[1]	V. rare, 1 @ Banir	1 @ Lim Chu Kang
Aethriamanta gracilis	Local	Common, widespread
Agrionoptera sexlineata[2]	Local	Local
Brachydiplax chalybea	Local	Common, widespread
Brachythemis contaminata	Rare	-
Camacinia gigantea[1]	Rare	Rare
Chalybiothemis fluviatilis	Local (MacRitchie)	No other records
Cratilla metallica	Occasional	-
Crocothemis servilia	Occasional	Common
Diplacodes nebulosa	Local	Common
Diplacodes trivialis	Local	Common
Lathrecista asiatica	Occasional	Frequent
Lyriothemis cleis[1]	Occasional	-
Nannophya pygmaea	Local but widespread	Local
Neurothemis fluctuans	Very Common	Very Common
Orchithemis pulcherrima	Common	-
Orthetrum chrysis	Common, open areas	Common
Orthetrum glaucum	Local	Common
Orthetrum luzonicum[1]	Local	Rare
Orthetrum sabina	Common	Common
Orthetrum testaceum	Common	Common
Pantala flavescens	Common	Common
Potamarcha congener	Occasional	-
Rhodothemis rufa	Local	Common
Rhyothemis obsolescens	Local	Local
Rhyothemis phyllis	Common	Common
Rhyothemis triangularis[1]	Local	-
Risiophlebia dohrni[1]	Rare, swamp forest	-
Tholymis tillarga	Common	Common

Species	Status in Nature Reserves	Singapore general
Trithemis aurora	Common	Common
Trithemis festiva[1]	Local (open stream)	Local
Trithemis pallidinervis	Local	Frequent
Tyriobapta torrida	Frequent	-
Urothemis signata[1]	Occasional	Frequent

More locally, open ground with wet areas supports the tiny *Nannophya pygmaea*, *Rhyothemis obsolescens* and common damselflies such as *Agriocnemis femina* and *Ceriagrion cerinorubellum*. The blue coloured *Pseudagrion*, *P. microcephalum* (Plate 2b) and *P. australasiae*, occur along open stream lines as well as around reservoirs. Large active libellulid dragonflies hover over and near open waters and include *Orthetrum sabina*, *O. chrysis*, *O. testaceum*, *O. glaucum* and *O. luzonicum*, *Crocothemis servilia*, *Rhodothemis rufa*, *Trithemis aurora*, *T. festiva*, and the smaller *Aethriamanta gracilis*, *Brachydiplax chalybea* and *Diplacodes nebulosa*. The large gomphid *Ictinogomphus decoratus* is also very common.

Open spaces far from water, especially high ground such as the helicopter landing site near Chestnut Avenue, also have large populations of *Rhyothemis phyllis*, *Pantala flavescens* and *Trithemis aurora*, and some rare records such as *Camacinia gigantea*. Road-sides with temporary pools may have local populations of *Diplacodes trivialis*.

Although these common species are likely to be those usually seen by the public, very few of them penetrate into truly closed forest (an exception is *Orthetrum chrysis*), and it is the forested water bodies that were the principal object of the present survey. Of the nine species originally collected by Wallace in 1854 and said to be based on Singapore material, all but one (*Libellago stigmatizans*) still survive and are found in the reserve. Of the others, *Libellago aurantiaca* is now confined to the Nee Soon drainage (but would probably have been collected by Wallace in the upper reaches of the Pang Sua, which would have been swamp forest at that time). Of the others, *Coeliccia octogesima* (Plate 3a), *Drepanosticta quadrata* (Plate 3b), *Onychargia atrocyana*, *Prodasineura interrupta* (Plate 3d), *P. notostigma* and *Agrionoptera sexlineata* are still found scattered widely throughout the central catchment area near forested streams or swamps. *Devadatta argyoides* is now virtually confined to Bukit Timah and *Teinobasis ruficollis* to secondary forest pools at the stream convergence of the Upper MacRitchie basin. Interestingly, this latter point would have been accessible by cart track in Wallace's day, though it is more likely that the species were more widespread in his day

Eight species now appear to be totally confined to the Nee Soon Swamp Forest, *Burmagomphus divaricatus, Heliogomphus kelantanensis, Libellago aurantiaca, L. hyalina, Microgomphus chelifer, Risiophlebia dohrni, Tetracanthagyna plagiata,* and *Vestalis amoena*. Six others, *Amphicnemis gracilis, Macrogomphus quadratus* (Plate 2c), *Orchithemis pulcherrima* (Plate 2d), *Prodasineura collaris, P. interrupta* and *P. notostigma*, are also common there, but extend elsewhere in forested streamlines.

Seven other species, *Archibasis viola, Drepanosticta quadrata, Euphaea impar, Onychargia atrocyana, Podolestes orientalis* (Plate 3c), *Tyriobapta torrida,* and *Vestalis amethystina*, occasionally appear in the fringes of the swamp forest but are more typical of feeder streams or swamps elsewhere in the catchment. Of these, *Euphaea impar* and *Vestalis amethystina* are believed to favour higher water speeds and often indicate erosion areas such as those in the Upper MacRitchie basin (Figure 2). The distinctive larva of *Euphaea* is found among trapped leaves in fast water.

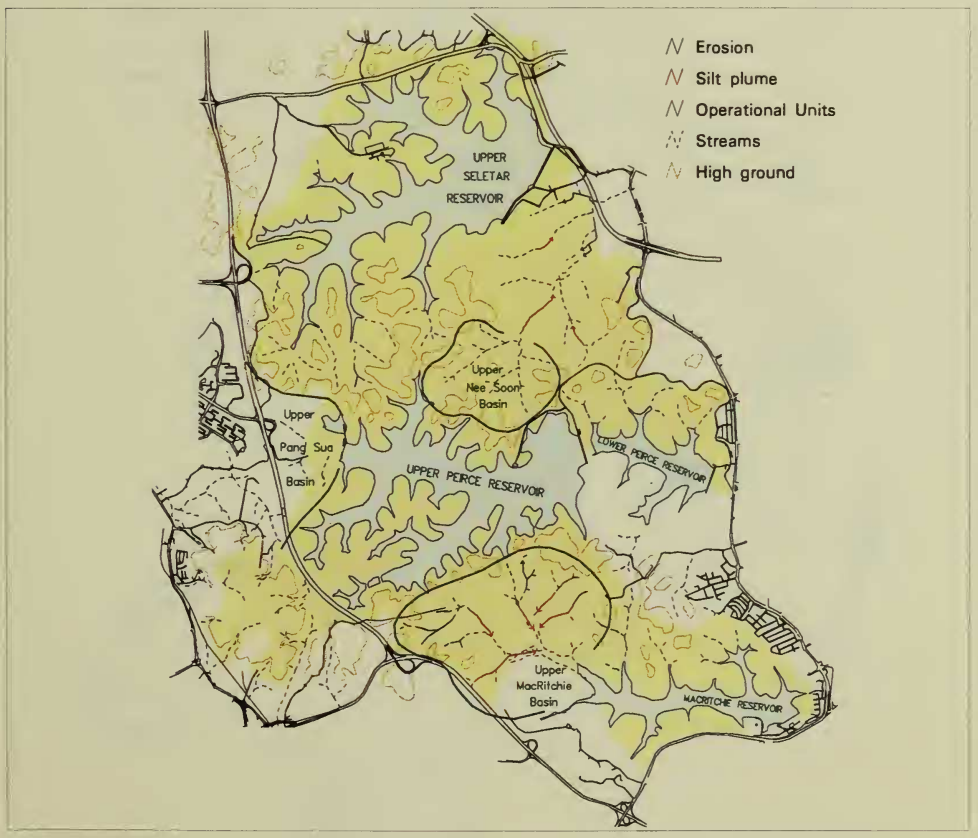

Figure 2. Sites of erosion processes currently or historically likely to have affected dragonfly distribution.

Secondary swamp forest variants also exist (Figure 3). At the head of inlets of the low-lying reservoirs (MacRitchie and Lower Peirce) where the stream profile is very shallow, long narrow 'ribbon swamps' with braided stream lines have developed since the impoundment. They have a very depauperate tree flora but offer conditions in which some of the swamp forest odonates, such as *Amphicnemis* and *Macrogomphus*, have become established. Higher up the water courses, uneroded streams often alternate between fast flowing reaches and level swampy reaches which I call 'step swamps'. Whether this is a general feature of granitic topography or perhaps a consequence of prior land use is uncertain, but some of the step swamps are particularly favoured by *Drepanosticta, Coeliccia, Podolestes* and *Archibasis viola*, though these species can certainly be found elsewhere.

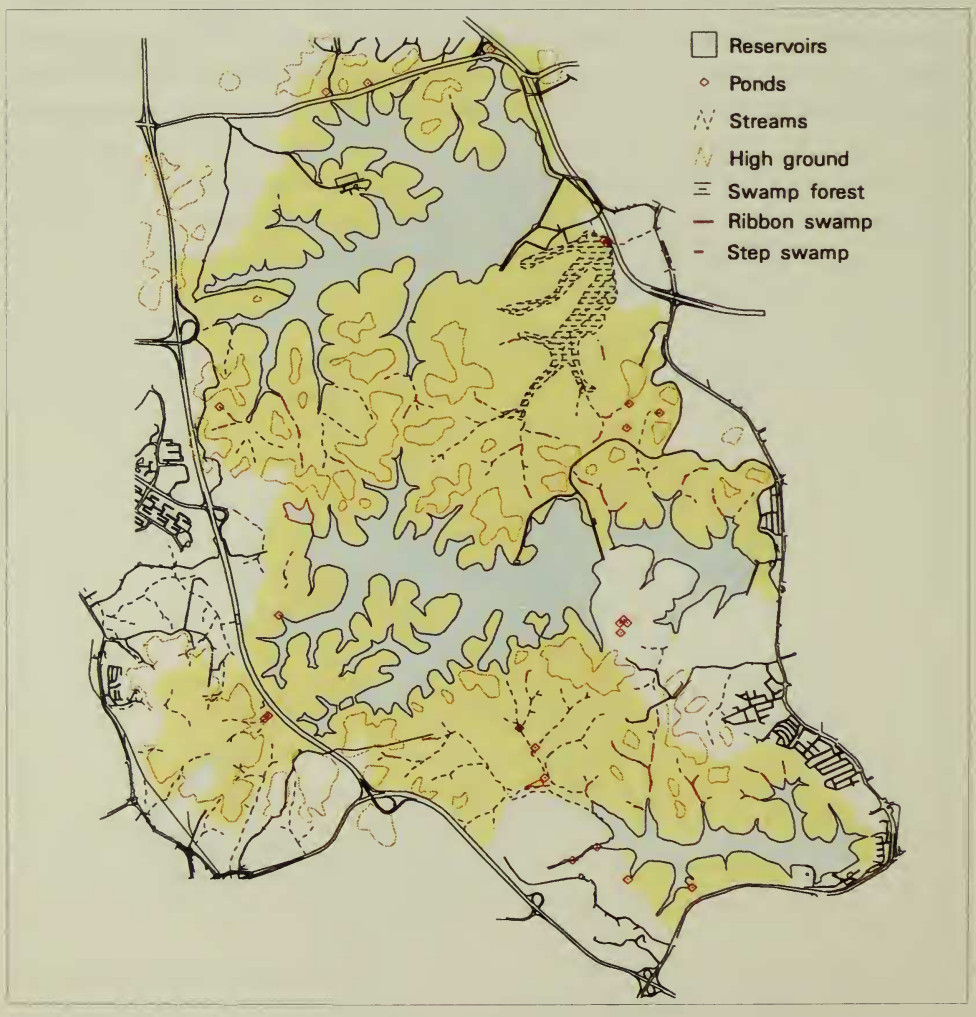

Figure 3. Distribution of various kinds of water body in and near the reserve area.

As an example of species distribution, Figure 4 plots records of the three species of *Prodasineura*. None of these have been found outside the CCNR in Singapore and the genus is not known from Bukit Timah. Too few larvae have been seen to throw light on breeding conditions and only one of these was reared to adult so we do not know how to discriminate species from larvae. Nevertheless, adult distribution shows intriguing differences. *Prodasineura collaris* is widely scattered and appears associated with still waters choked with leaves. *Prodasineura notostigma* is common over deeply-shaded open streams. *Prodasineura interrupta* occurred together with *P. notostigma* in the lower part of the Nee Soon Swamp Forest and was widespread in the upper Nee Soon basin where it was the only species seen. It remains unexplained why this species is, on present evidence, confined to the Nee Soon catchment, since it is found in riparian galleries not obviously different from those in other drainage systems. The absence of *P. notostigma* from the Upper Nee Soon basin is also remarkable.

Figure 4. Distribution of three species of *Prodasineura*.

The convergence streams and pools of the Upper MacRitchie basin (Figure 5) support some species not, or rarely, seen elsewhere. The artificially straightened lower reaches of streams H and J caused berms to impound ponds to which several rare species are now confined, notably *Argiocnemis rubescens* and *Teinobasis ruficollis*. Some of these ponds are fairly open with scattered emergent small trees of *Alstonia spatulata* but have well shaded edges, while smaller ponds under full shade also exist. Other species breeding here include *Tyriobapta* and *Lathrecista* that are more widespread. Also restricted to this area, but along the open streams, is *Agriocnemis nana*. Why this location should have localised species is not entirely clear. However it is speculated that these forest pools may represent a habitat formerly more widespread in lowland Singapore in situations now lost to urbanisation or cultivation. The species may have succeeded in colonising this secondary habitat before their original and natural habitats were completely destroyed. However there are possibly other contributing factors.

The recent appearance of *Pseudagrion pruinosum* and *Copera marginipes* in the nearby meter pond area may relate to seepage of enriched water from Upper Peirce, as may the presence of the calcareous alga *Chara*.

Figure 5. Location of the convergence streams and pools of the Upper MacRitchie basin.

Upper Peirce Reservoir is now principally a holding reservoir for water imported from Johore and has potassium levels ten times higher than that of purely local water. Similar levels occur in some headwater streams originating close to Upper Peirce but which feed into MacRitchie. Water quality may also be a factor in the presence of *Devadatta* in one location (MacRitchie stream J). This species is otherwise restricted to Bukit Timah whose streams also show higher potassium levels due to drainage from freshly decomposing granite. Throughout its wide range in South East Asia, *Devadatta* seems intolerant of the nutrient deficient waters typical of forest streams on deep mature regolith. In addition, meter pond stream H (Figure 5) until recently received water through the Kallang Tunnel also originating in Johore and the possibility of larvae having washed through cannot be discounted.

Dragonflies are less often seen in dry-land forest remote from water but certainly do occur there. This is especially true of females that may tend to leave the breeding sites to forage before returning to mate and lay eggs. Females of *Coeliccia octogesima, Vestalis amethystina* and *Amphicnemis* have been taken so, but never their males. This may be why *C. octogesima* was described from a female, while the actually more commonly seen males were unknown until this present survey. However, *Tholymis tillarga* males are quite often seen flying in deep shade. This species is commonly attracted to lights and is widely considered to be nocturnal, but in the forest it is clearly active in daytime. *Cratilla metallica* and one or more of the three species of *Gynacantha* known from Singapore are also seen in deep forest. *Pericnemis stictica* and *Lyriothemis cleis* breed in 'phytotelms' (tree-holes and bamboos holding water) and are apparently widespread, though not often seen as adults. Their habits would not restrict them to stream-lines.

The reservoirs themselves support some species not entering forest. The oldest reservoir, MacRitchie, has three species not found elsewhere, *Archibasis melanocyana, Chalybiothemis fluviatilis*, and *Lestes praemorsus* as well as common open-water species of *Orthetrum*, *Rhyothemis*, *Trithemis*, *Epophthalmia* and *Ictinogomphus, which* are found around all reservoirs and open streams throughout the island. The reservoirs have not been a major issue during this survey although, of course, some material has been assembled, including the three species confined to MacRitchie. Several species recorded only from other reservoirs are known to be associated with unstable or even maritime conditions (e.g., *Trithemis pallidinervis* and *Ischnura senegalensis).*

Of species known to be present in Singapore but not recorded during this survey of the CCNR, several are high flying or nocturnal forms that are certainly there but were not collected by the methods used. Several

very common forms associated with small open water bodies, maritime conditions or enriched or polluted waters are either absent or extremely local, as would be expected in a controlled water catchment where such habitats are excluded. Thus *Brachythemis contaminata* that is one of the commonest species around shallow grassy ponds such as exist in the nearby golf courses, is hardly ever seen even in immediately adjacent arms of the reservoirs.

Discussion

Of the recorded names accepted as valid, seven are considered suspect as records. *N. tullia*, *P. laidlawii* and *Rhinocypha* sp. were listed from Nee Soon in a publication in Japanese attributed to Iwasaki (1981) after his death. On translation this proved to be his edited field notes, originally using Japanese names of Japanese species with which he was familiar, but with scientific names added apparently by an editor. He appeared to have been unfamiliar with tropical species at the time of collection and used Japanese species names as a rough guide, the editor then attempted to match these with known regional species. His exact collecting sites were mapped and have been revisited but none of his species were found there. His *N. tullia* may be *Tyriobapta torrida*, and *P. laidlawii* may be *Prodasineura collaris*, the only species now found at that site. Several other names though valid are to some extent suspect. Thus, *Vestalis amethystina* is recorded from where we now find only *Vestalis amoena*, possibly because former records of *V. amoena* from Singapore have been revised as *V. amethystina* (Lieftinck, 1965) and we now know that both species occur. *Agriocnemis pygmaea* was reported with a note that its thorax was unusually thick compared with Japanese material. Today the site has only *Agriocnemis femina*. That there could have been faunistic changes is, of course, possible especially since oiling for mosquito control is carried out at the site specified.

One record of *N. intermedia* by Yokoi (1996) from a site near the Zoological Gardens is unlikely since the species is Indian. Possibly this was *Neurothemis disparilis*, also a species we have failed to recognise. Material from Bukit Timah attributed to *Indolestes* by Murphy and given to D. Paulson in 1980 may be the origin of his informally circulated record of *Platylestes heterostylus*.

The widely cited records of *Urothemis abbotti* appear to originate from the original author (Laidlaw, 1927) mentioning a damaged female Singapore specimen when describing *U. abbotti* from Thailand. All material of this genus examined since have proved to be *Urothemis signata bisignata*. A record of *Orolestes wallacei* by Laidlaw (1931) was based on a specimen

"said to be in the British Museum and not seen by me...". It is a possible record but remains unconfirmed to this day.

A total of 24 species collected during this survey are new records for Singapore (Table 1). Some of these are common and were to be expected. In total, 79 species have been recorded as documented specimens from within reserve limits with a further eight likely to be present but with habits precluding collection, such as being nocturnal or high flying. The species listed as now confined to Nee Soon Swamp Forest were probably more widespread in the past. *Vestalis amoena* was historically recorded (correctly) from Bukit Timah. Two species are distinctive of Bukit Timah - *Indolestes* and *Devadatta argyoides*. All other species so far known in Bukit Timah also occur in the CCNR. The hill does, however, need more intensive survey than it has received.

An additional eight species recorded more or less reliably in the literature have not been seen (or at least recognised) but are not necessarily forms to be expected in the reserve area. Some may have habits (such as high perching) that preclude easy collection and only an extended rearing programme would be likely to reveal them. Only for three species, normally associated with habitats such as large rivers that have now been totally converted in Singapore, can extinction be strongly suspected.

Five historically recorded species may have become extinct - *Brachygonia oculata*, *Burmagomphus plagiatus*, *Dysphaea dimidiata*, *Libellago stigmatizans* and *Neurobasis chinensis*. *Burmagomphus plagiatus* was a reliable larval record by Lieftinck (1964) from the lower reaches of Seletar River now converted to a concrete canal. In addition, *Neurothemis disparilis*, *Agriocnemis pygmaea* and *Rhyothemis pygmaea* have not been seen by me, although records of the latter two by Paulson in 1980 are recent. Even so, none of the extinctions can be taken as absolutely certain, although very probable.

Among Odonata, only one species (*Drepanosticta quadrata*) is believed totally endemic to Singapore, but it is common in several areas and is not threatened. The genus is known for having many extremely localized species.

Many species are more or less restricted to tree covered land and most of these found only in the CCNR and/or Bukit Timah. These include the eight species mentioned above as only known today from the Nee Soon Swamp Forest.

The deteriorating conditions in the Upper MacRitchie Basin are reflected in the odonate fauna in several ways. An apparent extinction that occurred within the last three decades concerns *Neurobasis chinensis* (last taken in Singapore in 1970), extinct probably due to siltation of the stream marked Jc (Figure 5) where it occurred by construction of the Pan Island

Expressway in 1972. A stand of mature riparian swamp forest in the upper reach of that stream died out at that time. By 1990 good regrowth had developed but then the expressway was widened and the whole streamline again smothered by a new silt surge. Well-established local populations of *Amphicnemis* and *Coeliccia* died out, together with the young secondary swamp forests in which they had become established between 1993 and 1994. Possibly *Onychargia*, not seen there since 1989, was also lost. These species, which are still present elsewhere, will probably recolonise sites that revert to forest cover. In the lower reach, a population of *Agriocnemis nana* was destroyed along with other species and only *Trithemis aurora*, a 'weedy' species not formerly present, is found there today.

Finally the question of seasonality has hardly been addressed. Most species are not significantly seasonal on a regular basis, but some migrants may be affected by the monsoons. Periods of drought may cause smaller water bodies to dry out entirely with possible long term consequences for species with poor dispersal.

Acknowledgements

My thanks to my student helpers, all engaged in collecting and who did most of the mapping work who are too numerous to name, but Tan Hoe Teck and Lim Koon were the longest serving and most expert; Mrs. Yang also fielded teams of collectors who took some material; Dr. Matti Hämäläinen of Helsinki visited Singapore after the project was completed and who kindly corrected my misidentifications, detected a specimen of *Coeliccia albicauda* among Mrs. Yang's material and provided some references I had overlooked; Dr. Tan Koh Siang made lengthy translation from Japanese text that clarified some important issues; and the staff of the National Parks Board who have been continually supportive as have my colleagues at the Department of Biology, National University of Singapore.

References

Corlett, R.T. 1992. The changing urban vegetation . In: A. Gupta & J. Pitts. *Physical Adjustments in a Changing Landscape: The Singapore Story*. Singapore University Press. pp. 190–214.

Iwasaki, M. 1981. Field observation notes in Malay Peninsula and Sumatra. *Gracile*. **28**: 12–26. (in Japanese).

Johnson, D.S. 1967. On the chemistry of freshwaters in southern Malaya and Singapore. *Archiv fuer Hydrobiologie.* **63**: 477–496.

Kiauta, B. & M. Kiauta. 1982. The chromosome numbers of eleven dragonfly species from Singapore. *Notulae Odonatologicae.* **1**: 164–165.

Laidlaw, F.F. 1927. Description of a new dragonfly from lower Siam belonging to the genus *Urothemis*. *Proceedings of the United States National Museum.* **70**: 1–3.

Laidlaw, F.F. 1931. A list of the dragonflies (Odonata) of the Malay Peninsula with descriptions of new species. *Journal of the Federated Malay States Museums, Singapore.* **16**: 175–233, figs. 1–7.

Lieftinck, M.A. 1954. Handlist of Malaysian Odonata. A catalogue of the dragonflies of the Malay Peninsula, Sumatra, Java and Borneo, including the adjacent small islands. *Treubia. Suppl.* **22**: i - xiii, 1–202.

Lieftinck, M.A. 1964. Some Gomphidae and their larvae, chiefly from the Malay Peninsula (Odonata). *Zoologische Verhandelingen (Leiden).* **69**: 3–38.

Lieftinck, M.A. 1965. The species group of *Vestalis amoena* Selys, 1853, in Sundaland (Odonata, Calopterygidae). *Tijdschrift voor Entomologie.* **108**: 325–364.

Murphy, D.H. 1994. *Risiophlebia dohrni.* In: P.K.L. Ng & Y.C. Wee (eds.). *The Singapore Red Data Book: Threatened Plants and Animals of Singapore.* The Nature Society, Singapore. pp. 107.

Paulson, D. (undated) *Singapore Odonata collected 29 August 1980.* Unpublished report.

van Tol, J. 1992. An annotated index to names of Odonata used in publications by M. A. Lieftinck. *Zoologische Verhandelingen (Leiden).* **279**: 1–263.

Wallace, A.R. 1855. The entomology of Malacca. *Zoologist.* **13**: 4636–4639.

Williams, F.X. 1936. Biological studies in Hawaiian water-loving insects. *Proceedings of the Hawaiian Entomological Society.* **9**: 235–345.

Yokoi, N. 1996. A record of the Odonata from Mandai, Singapore, *Malangpo* (Newsletter of the Thai National Office of the International Odonatological Society) **13**: 100.

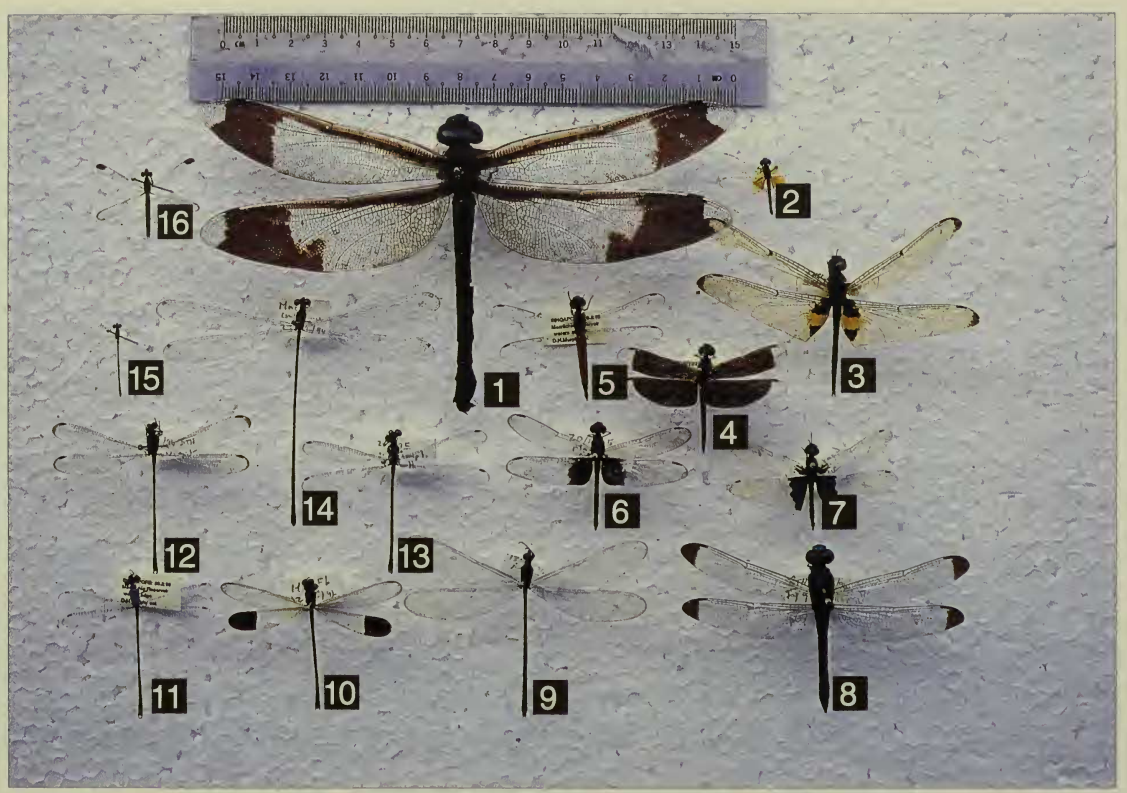

Plate 1. Some Singapore dragonflies and damselflies to show relative sizes; 1—8 Suborder Anisoptera, 9—16 Suborder Zygoptera. **1**. female *Tetracanthagyna plagiata*. **2**. *Nannophya pygmaea*. **3**. *Rhyothemis phyllis*. **4**. male *Neurothemis fluctuans*, two commonly seen open country species. **5**. male *Orchithemis pulcherrima*, the commonest dragonfly over forest streams. **6**. male *Tyriobapta torrida*, a forest species often seen perching on the vertical side of tree trunks. **7**. male *Rhyothemis triangularis*. **8**. *Cratilla metallica*, one of the larger Libellulids. **9**. *Vestalis amethystina*. **10**. *Euphaea impar*. **11**. *Lestes praemorsus*. **12**. *Devadatta argyoides*. **13**. *Podolestes orientalis*. **14**. *Pericnemis stictica*. **15**. *Agriocnemis femina*. **16**. *Libellago aurantiaca*.

Plate 2. **a**. *Aethriamanta aethra*, a first record for Singapore. **b**. *Pseudagrion microcephalum* occurs along open waters such as grassy streams and edges of reservoirs. **c**. *Macrogomphus quadratus*. **d**. *Orchithemis pulcherrima*.

Plate 3. Some damselflies widespread in forest stream-lines (a—c) and a species from the Family Protoneuridae (d). **a**. Male *Coeliccia octogesima*. **b**. *Drepanosticta quadrata* is believed to be endemic to Singapore. **c**. *Podolestes orientalis*. **d**. *Prodasineura interrupta*.